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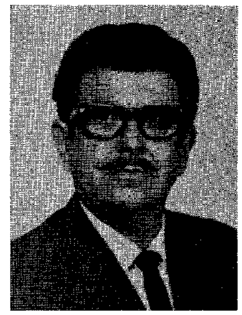
View of the Earth from Space[1]



Robert E. Stevenson, Galveston, Texas[2]

The day is past when we merely talk or warn of the need for conservation and management of natural resources. Present requirements of undernourished and underpriviledged people are so great that if they are not met, political and economic, if not military, revolution will result. It is absolutely necessary, therefore, that the public recognize the relationships of the earth processes, forces and energies. Interaction of sea, air, and land must be better understood by everyone—otherwise, we will not be able to rationalize pollution control, efficient land use, and resource management, or realize the need for international natural resource treaties.

How do we make these relationships understandable?

A major problem for the student is the concept of magnitude. It is difficult for one to appreciate estuarine pollution without seeing an estuary. Nor can one realize the close relationship of coastal circulation to coastal geography without a concept of the magnitude of the interaction.

Furthermore, people must know the scale of the system to answer reliably such questions as: What is the most economic return from coastal utilization—housing, industry or natural fishery nursery grounds? What are the problems of thermal water pollution? Where is air pollution most likely to occur and what does the landscape-atmospheric reaction have to do with it? Without this knowledge, understanding is limited and answers are clearly provincial. Consequently, to ask legislators to vote on laws or regulations relating to these problems becomes useless.

Efficient management of the ocean, atmosphere and land resources must be established. It is the only solution to a peaceful, happy, growing society. To accomplish this goal, there must be an aware public.

A new tool is now available to education—the view of the earth from space. Student and teacher now have the opportunity to "see" the results of land-sea-air interactions on visual scales of sufficient magnitude to depict the significant major natural processes. Furthermore, the "view" is repetitive so that the changing forces, and reactions to them, can be followed. As a result, an understanding of the dependence of land features on air-sea reactions, of ocean motions on air-land interactions, and of atmospheric conditions on the land-sea relations can be greatly advanced.

BARS AND THE BAHAMA BANKS

An excellent example of land-sea-air interactions is provided by photographs of a portion of the Bahama

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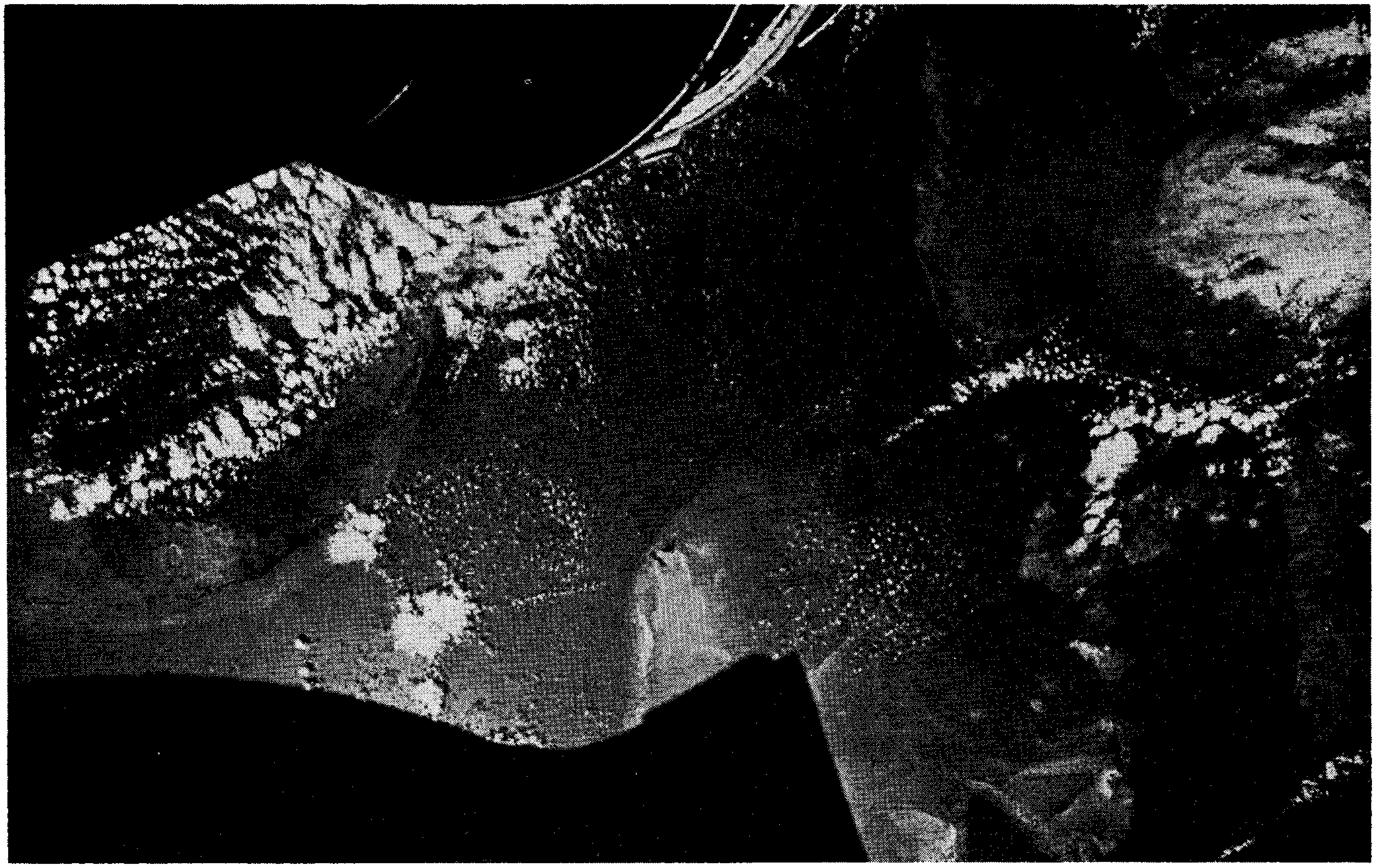

Figure 1. Southern Florida, Florida Keys, Florida Straits, and portions of the Bahama Islands and the Bahama Banks, Gemini flight XII, November 12, 1966, by astronauts Capt. James A. Lovell, Jr. and Lt. Col. Edwin E. Aldrin, Jr. NASA/MSC No. S66-62838.

Islands. In Figure 1, Florida Bay, the Florida Keys, and the Florida Straits can be seen beneath the open door of the spacecraft. Across the channel of the Florida Straits are the northern part of Greater Bahama Bank, the island of Bimini, the Berry Island group, the northern part of Andros Island; New Providence Island, and the city of Nassau. Under the nose of the Agena rocket are Grand Bahama Island, Little Bahama Bank, and the clouds overlying the waters of the Gulf Stream.

This photograph is particularly interesting because of the clear relationships of the shallow, calcareous sandbars which can be seen on the Great Bahama and Little Bahama Banks. Immediately to the south of Bimini Island are a number of large, more or less U-shaped bars that indicate the spillover of water onto the shallow platform of a portion of the Grand Bahama Banks. Similar spillover bars are present around the Berry Island group and the northern end of Andros Island (Figure 2). It is clear that in each area rising, flooding waters spill toward the central portion of Grand Bahama Bank. Near the top of the picture is a long sandbar where rising, flooding waters meet. On ebb tide, the waters recede into the channel between the Grand Bahama Bank and Grand Bahama Island to flow out into the Gulf Stream and then north into the Atlantic Ocean.

The flooding waters that form these large, magnificent bars are the result of great storm surges, coming primarily from the force of hurricane winds on the sea. Consequently, a sequence of interacting events exists which, when completed, leave their "mark" in the form of the flood and ebb spillover bars. The force of atmospheric winds on the sea necessary to produce the surging, rising waters that flood over the shoal Bahama Banks is easily imagined from the visual examination of sand bars 8 to 60 kilometers long.

DIAMONDS AND THE COASTLINE

Another sequence of natural events can be studied from the Gemini IV photograph of the Walvis Bay coast, Southwest Africa (Figure 3). This photograph of a cloud-free region is unusually detailed, for the photo resolution is the order of 30 meters or better. For example, the highway connecting Walvis Bay with Windhoek, as well as other small features such as the surf, can be seen clearly.

The area is largely a desert. Although most of southwest Africa consists of high plateau 1,000 meters or more in elevation, the coastal region, varying between 100 to 150 kilometers wide and about 500 kilometers long, is barren desert. None of the rivers within the limits of the photograph, nor for a considerable distance to the south, are perennial. The Swakop River is dry except for 1 or 2 months in the summer.

Because the region is a desert, with little or no surface runoff, turbid water normally would not be expected offshore. Careful examination of the photograph,

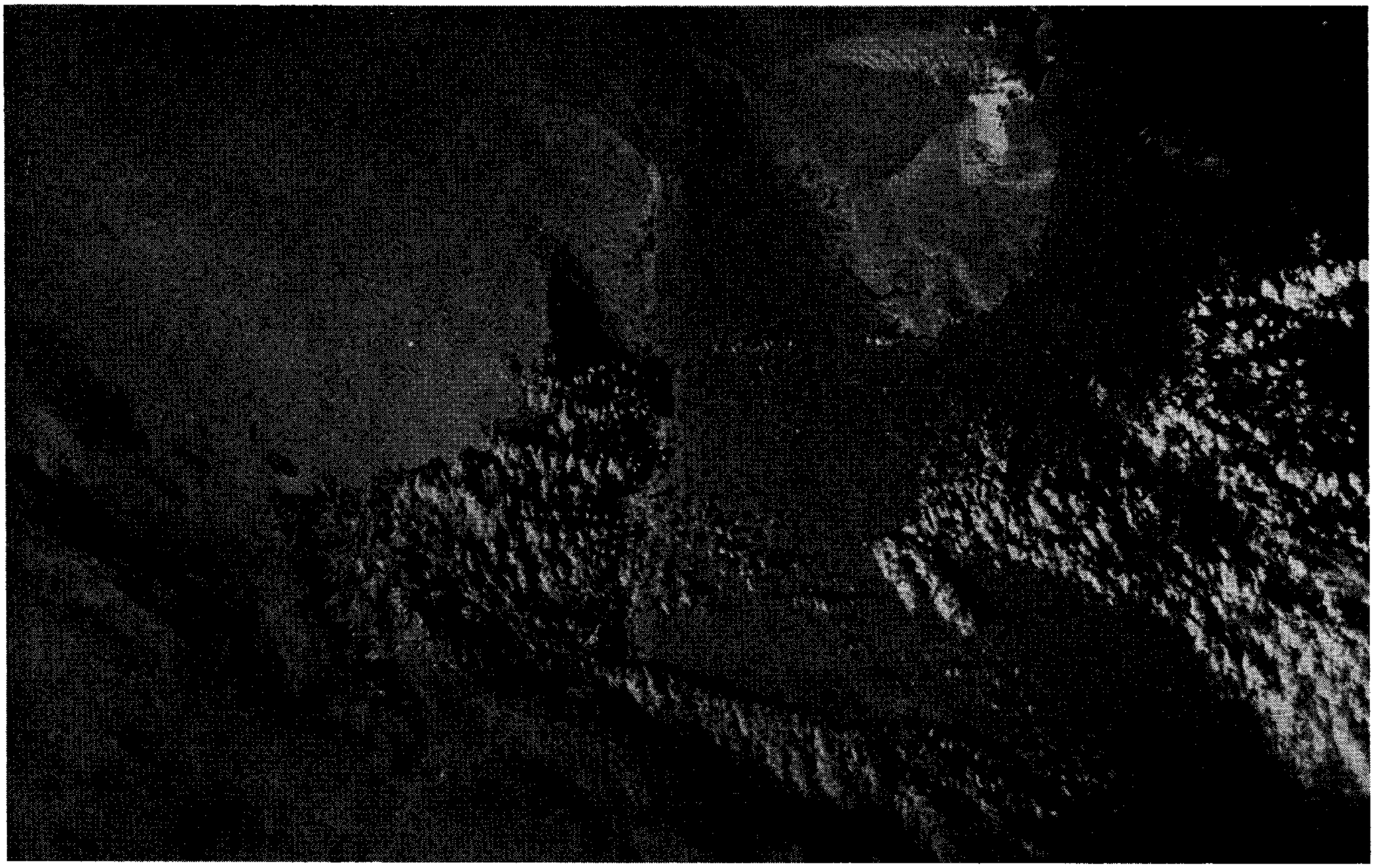

Figure 2. Northern end of Andros Island, Berry Islands, New Providence Island, and a portion of the Great Bahama Bank, Gemini flight VII, December 5, 1965, by astronauts Col. Frank Borman and Cdr. James A. Lovell, Jr. NASA/MSC No. S65-64956.

however, shows some evidence of turbidity. It is probably of biological origin.

An interesting observation is the distance that the average sea breeze penetrates inland. The ridge dunes dissipate rather abruptly near the coast in a confusion of small sand dunes. The landward edge of the disorganized dunes marks the penetration of the sea breezes.

The exceptionally dry climate is in response to the effects of the northward-flowing, cold Benguela Current. The air above the current is cooled so that little moisture is derived from the sea. Winds from the east are dry, having traveled over hundreds of kilometers of arid land.

Prevailing winds blowing towards the ocean produce the distinctive dune ridges that are oriented almost perpendicular to the direction of the wind. These long dunes are a result of winds blowing from nearly the same direction for centuries. Inland are the famous "diamond pipes" of South Africa. Diamonds weathered from the volcanic rocks have been, and are being, carried with the migrating sand to the coast. There, intense wave action from the South Atlantic Ocean has concentrated the diamonds on the shallow seafloor. There lie today the richest marine deposits known to man.

The white fringe along the shore, like a string of pearls, is caused by huge waves (typical of this shore) breaking nearly 200 meters from the beach. Rip currents about 1,000 meters long reflect in the sunlight and are the largest of the shoreline "pearls." Such intense surf action is normal and produces the great turbulence that transports the sand north along the coast and leaves the residual diamond concentration.

GREAT EDDIES AND THE TEXAS COAST

Systems of rip currents, reacting to the same causes as those formed in the surf along the southwest African coast, are formed over the Texas Shelf, but on a scale measured in tens of kilometers rather than meters. Examples are seen in the Gemini XII photograph of the Texas and Louisiana coast, taken by Lt. Col. Edwin E. Aldrin, Jr. on November 14, 1966 (Figure 4).

The skies were clear and the air was dry following the strong intrusion of continental air after a cold front crossed the coast on November 12. Winds were still blowing from the northeast on November 14, as can be noted from the seaward drift of smoke from a marsh fire along the Louisiana coast and the southwestward drift of industrial haze from the city of Houston.

In response to the brisk (22 kilometers/hour) northerly winds that had been blowing for two days, the coastal currents were flowing to the southwest. As during every strong northerly wind along these coasts, the water in the lagoons and estuaries was pushed into the Gulf of Mexico. Sediment-laden water (light) is seen

Figure 3. Southwest Africa, Port of Walvis Bay and the restricted diamond area, Gemini flight V, August 27, 1965, by astronauts Col. L. G. Cooper and Cdr. Charles Conrad, Jr. NASA/MSC No. S65-45524.

to be flowing out through Sabine Pass and between the jetties at Galveston Bay.

In Galveston Bay, the dark line is the dredged Houston Ship Channel and, in the northern part of the Bay, the light-colored streak extending from the mouth in the lower bay is extremely turbid water flowing from dredging operations.

The lighter coloring off the coast is turbid water spreading from the coastal lagoon complexes. An interference eddy has formed to the west of the Galveston jetties—the downstream side, here. Farther seaward, great eddies extend 45 to 150 kilometers from the coast over the shallow shelf (a depth of 100 meters is 200 kilometers from shore). These systems carry vast quantities of water from the nearshore shelf off Texas out into the Gulf of Mexico, thus relieving the build-up of sea level in the northwest Gulf much in the same manner that rip currents relieve the rising levels in the surf zone. The magnitude of the system in the northwest Gulf of Mexico is startling, for the seaward-flowing, turbulent currents must be permanent features of the waters over the Texas shelf although the position must

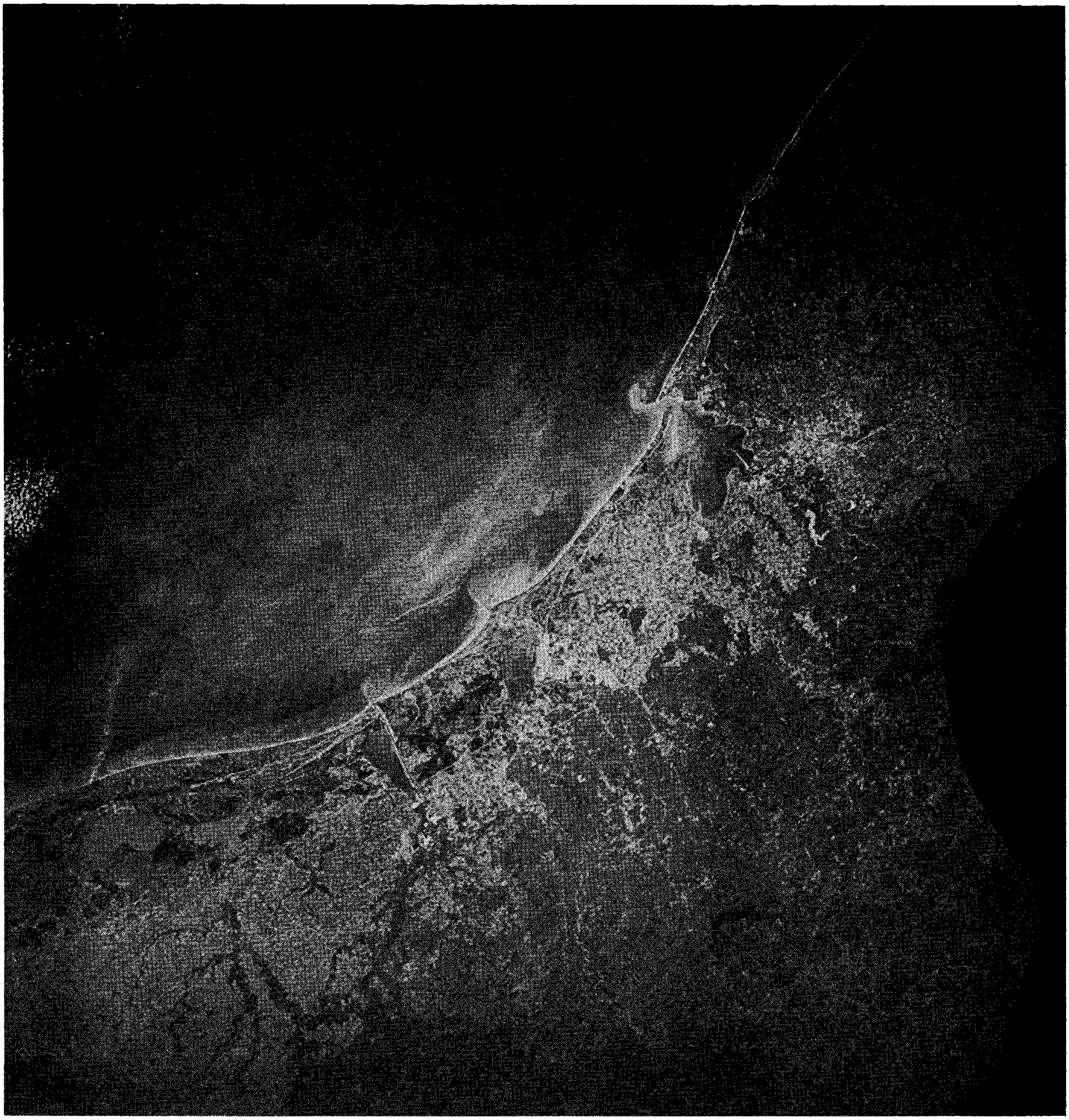

Figure 4. Texas and Louisiana coast, Gemini flight XII, November 14, 1966, by astronauts Capt. James A. Lovell, Jr. and Lt. Col. Edwin E. Aldrin, Jr. NASA/MSC No. S66-63184.

vary with the seasonal change of winds.

CLOUDS, WINDS AND CONVERGENCES

The distribution of turbid water can depict the relationships among coastal currents, tides, river discharge, and the lower atmosphere. A series of photographs taken by Gemini X astronauts along the coast of Surinam provides suitable examples.

Photographs off Surinam taken on July 21, 1966, show sediment-laden water poured out by the rivers and spread west along the shore. About 15 kilometers offshore the water turbidity indicated a flow to the east. The general current direction in these waters of the tropical Atlantic Ocean is to the west at velocities of 2 to 5 kilometers/hour. The distribution of the turbid water depicts, therefore, a current shear paralleling the coast.

The circumstances under which these currents and shear zones develop are not precisely known, and a considerable amount of detailed oceanographic research must be accomplished to interpret accurately the data derived from spacecraft.

Figure 5. Southern Gulf of California, Baja California and the city of La Paz, Santa Cruz Island San Diego Island, San Jose Island, Espiritu Santo Island, and the northern end of the island of Cerralvo, Gemini flight XI, September 14, 1966, by astronauts Cdr. Charles Conrad, Jr. and Cdr. Richard F. Gordon, Jr. NASA/MSC No. S66-54761.

The suspected cause off the shores of Surinam is the tide. In these waters, the tide rises to the east and ebbs to the west. Because greatest velocities are next to the coast, the pattern observed was probably formed throughout a tide cycle. The muddy water showed the tide ebbing (at the time of the photograph studied) after a strong easterly flood 2 or 3 hours earlier. Lines of cumulus clouds extended northeastward and produced a convergence in the lower atmosphere—the marine friction layer. Air rising to form the cumulus was drawn in from the sides thereby producing the converging winds. These convergences were minor—not like those of a frontal system—and the winds and pressures developed would not appear on the usual synoptic weather map.

Under some conditions, the winds drawn into the atmospheric convergence move the surface waters to form a convergence in the sea. This kind of action occurred off Surinam on this day where the cloud lines were associated with the boundaries of turbid water.

A FISHERY RELATED TO THE CONFIGURATION OF A COASTLINE?

The southern Gulf of California with the city of La Paz on the left and the Mexican mainland on the right

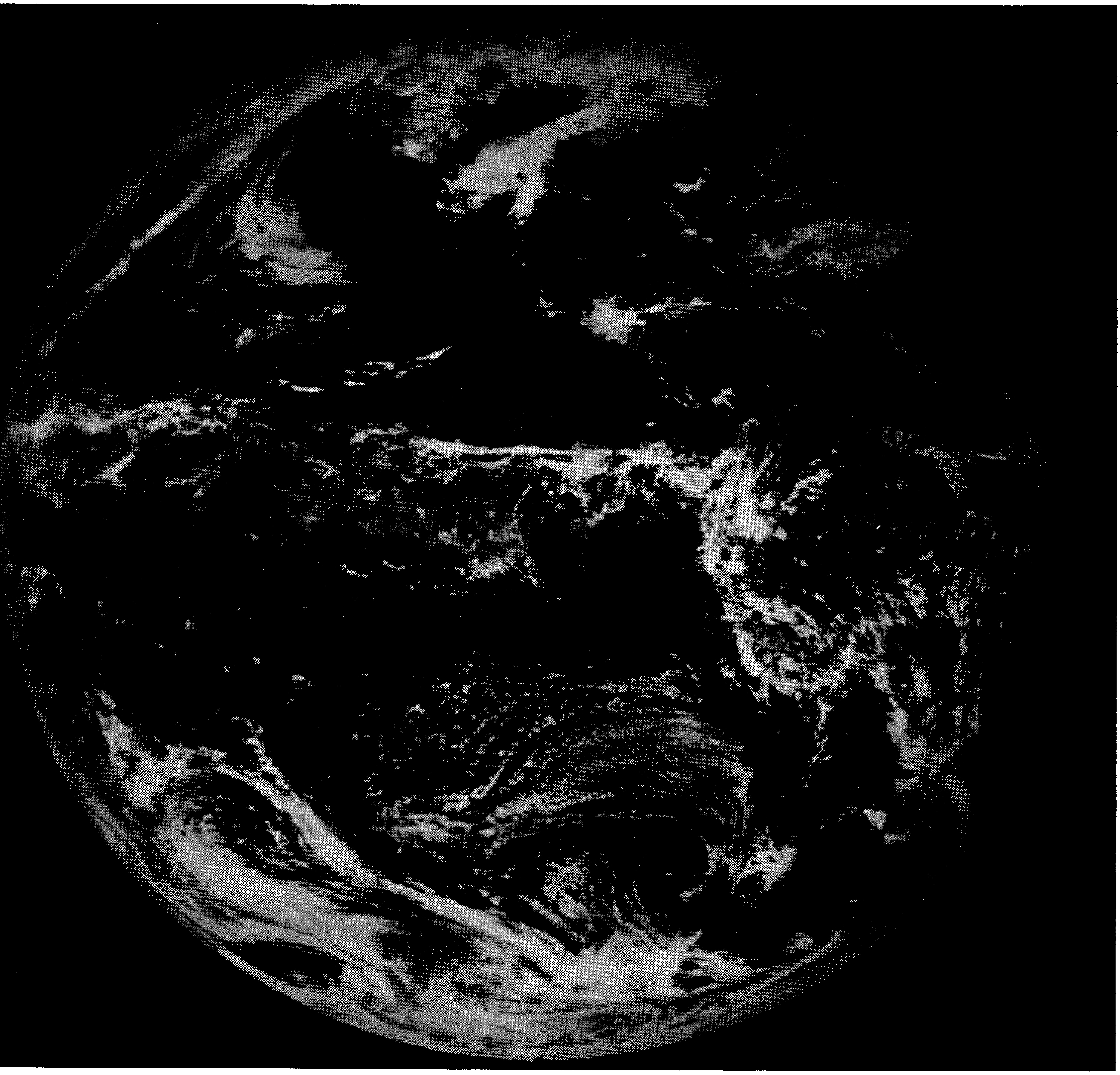

Figure 6. South America, Central America, Cuba, and portions of North America and the African continent, Application Technology Satellite III (ATS-III), January 18, 1968. NASA/MSC Color No. 193343Z.

was viewed by the Gemini XI astronauts September 14, 1966 (Figure 5). The edge of the sun's reflection is in the lower part of the photograph.

Of interest here are the slick in the strait between the La Paz coast of Baja California and the island of Cerralvo, the straight line of clouds to the north of the island of Cerralvo, and the large convergence under a long line of cumulus angling across the lagoons of the Mexican mainland coast. The slick pattern indicates water motion through the strait to the north, with a turbulent eddy north of Cerralvo. A convergent line in the water and in the overlying air lies to the northeast of the island.

Most impressive, however, is the convergence extending toward the Mexican mainland in a northeast-southwest direction. The flooding tide pours north into the Gulf of California from the Pacific Ocean and meets beneath the cumulus line those waters moving on the preceding ebb tide. The result is a strong convergence of waters with different temperatures marked by an overlying line of cumulus.

Winds on this day were easterly and hence the cumulus line formed on the warm side of the convergence. Flotsam, jetsam and food concentrated in the convergence provide excellent feeding for large fish such as marlin. The convergence line marks the great marlin fishing grounds off Baja California.

THE LONG RED SEA AND THE CURVED EARTH

The linear Red Sea lies in a graben produced by major rift faulting (cover photo). It is to this portion of the earth's crust that many advocates of continental drift point as evidence of continued rifting of large land masses. The features of mountains and coast are truly impressive examples of crustal faulting.

The long, straight, Red Sea Basin provides an unusual opportunity to identify with the curvature of the earth. Personal identification with the curved earth is difficult for anyone. We have known about the oblate spheroid from our youthful days and the stories of Columbus. Even so, and even with such phenomena as ships disappearing over the horizon, any "feeling" of a curved earth is rare. Consequently, photographs from space that show land features that can be related to a personal experience such as mountains, beaches, and rivers provide the perfect "identifier" of the round earth. This photograph, taken by Lt. Col. Edwin E. Aldrin, Jr. during the flight of Gemini XII, is one of the best "curved earth relators" that I have seen.

One may also understand from this photograph the reasons for the magnitude of air-sea interaction over the Red Sea—the merciless exposure to a cloudless atmosphere. The high salinity (40‰) and high temperatures (32° C.) of the water, the calcareous reefs (near the mouths of the Gulfs of Suez and Aqaba), the barren landscape, and the rigorous living conditions, can all be vividly imagined. Here too one can easily recognize the land modification and management practices that are so vital to the people in the Nile River Valley.

A NEW VIEW EVERY DAY

The view of the earth must be repetitive to follow the dynamic processes in the ocean and atmosphere. This repetitive view is easily available from satellites that are in a "parking orbit" (Figure 6). This view of the earth is from the color television camera on the Application Technology Satellite Number III (ATS-III) when it was situated over the Equator and at 84° W. longitude. A picture was transmitted every 20 minutes during the day so that the moving clouds and ocean currents could be plotted easily.

The picture reproduced in Figure 6 was taken at noon, local time, on January 18, 1968. Three major frontal systems can be seen in the northern hemisphere angling from northeast to southwest. The clouds of the Intertropical Convergence Zone extend east and west across the Pacific Ocean just north of the equator. Nearly clear skies lie over the warm equatorial current.

Our technology in satellite systems not only provides views of the magnitude seen from ATS-III, but also can provide photographic scales suitable to any user. Furthermore, such systems can readily bring this view and any other into any classroom in the world, whether it be the red brick buildings of Brooklyn, the stucco and redwood of southern California, or the thatched-roof huts in Samoa.

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